Joining and Testing Composite Plates to Ti Tubes

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The joining of metal tubes to composite plates is required for heat-rejection components in several space applications. Currently a number of different braze compositions are being evaluated as to their effectiveness. Such tube-plate configurations cannot be represented by traditional methods of testing, e.g., lap joints. The joined region is not between two flat surfaces, but rather between a flat surface and a curved surface. Therefore, several tests have been employed to ascertain the effectiveness of the different braze approaches in tension that are both simple and representative of the actual system and relatively straightforward in analysis. The results of these "tube tests" will be discussed for the three different braze compositions, Cu-ABA, Ti-Cu-Sil, and Ti-Cu-Ni. In addition, fracture analysis of the failed joints was performed and offers insights into the cause of joint failure and the distinctions which need to be made between the "strength" of a joint versus the "load carrying ability" of a joint.

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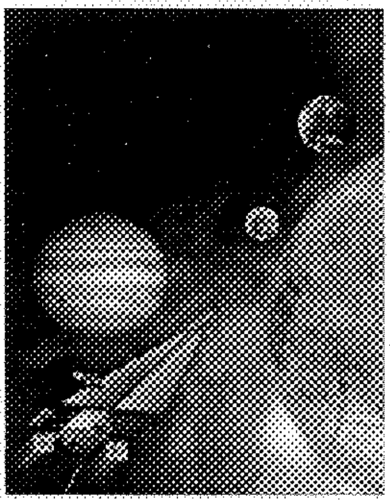

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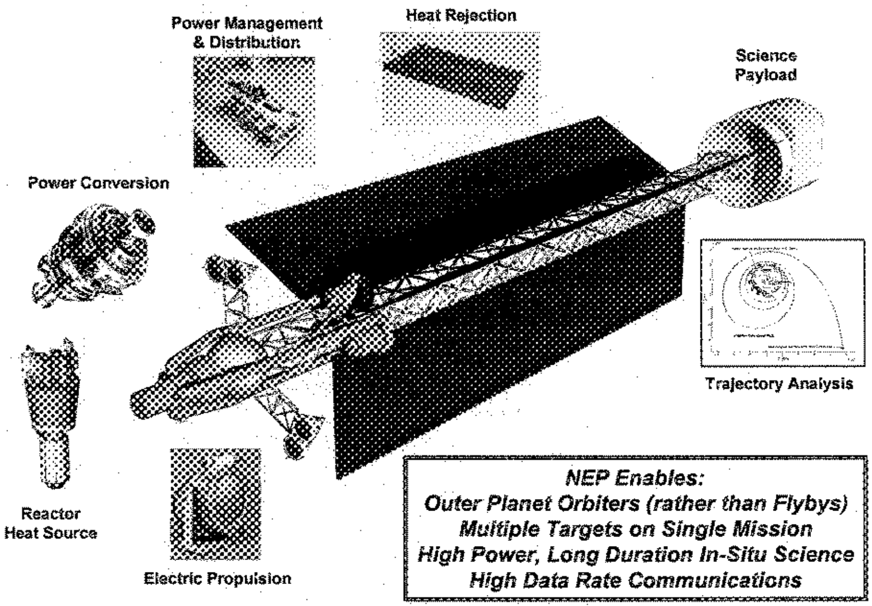
JUPITER ICY MOONS ORBITER

Exploring the habitable water worlds of Jupiter – Callisto, Ganymede and Europa

Nuclear Electric Propulsion Technology Critical to Space Exploration



NEP Enables:
Outer Planet Orbiters (rather than Flybys)
Multiple Targets on Single Mission
High Power, Long Duration In-Situ Science
High Data Rate Communications

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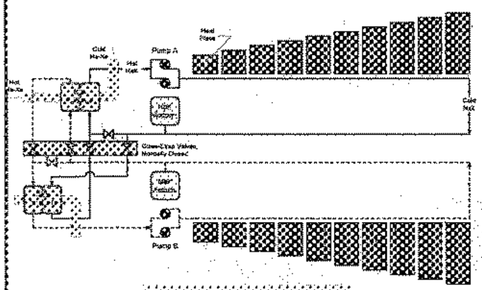
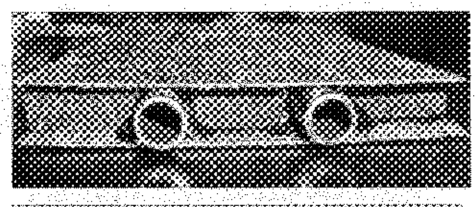
Assembly and Brazing Technology Development

Advanced C/C Composites Radiators for JIMO Heat Rejection System



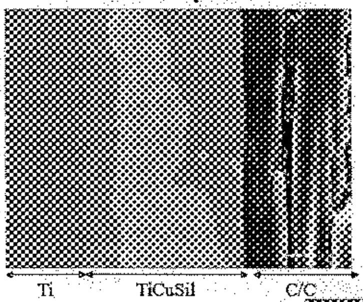
Advanced C/C Composite Radiators

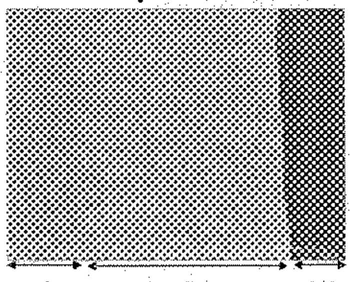


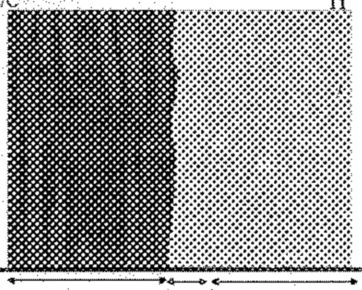
Assembly of Composites with Titanium Tubes

Metal-Ceramic Brazing Technologies are being developed for the robust assembly and integration of JIMO heat rejection system components

Good Bonding Between Flat Plates of Braze Compositions to Ti and C-C Composites





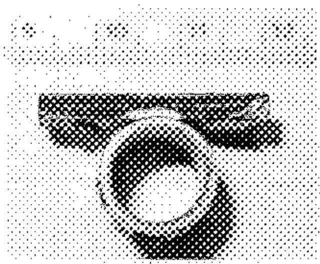


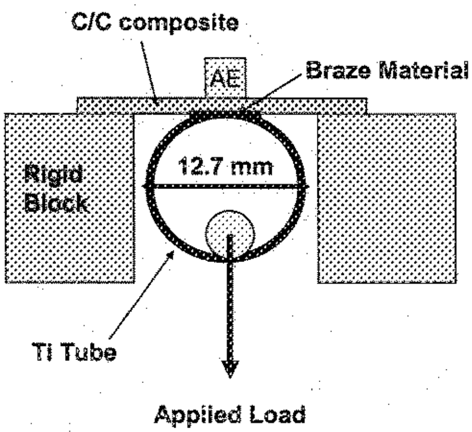
Objective

- To assess different braze compositions and tube-plate attachment schemes
  - How do you quantify load carrying ability when joining tubes to plates?
    - Both are not flat surfaces
    - Contact "area" may differ depending on joining method, surface tension, etc…
- Traditional approaches such as lap tests aren't useful → *NEED FOR A SIMPLE TEST*

Tube Tensile Test

To measure the "tensile strength" of the joint





Factors to consider:
-Braze composition
-Processing variables
-Bonded area
-Location of failure
-Architecture effects

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Experimental: Processing

- Tubes (12.7 mm diameter) joined to T-300 C/C plates (C-CAT Composites, TX) using three braze compositions (Morgan Advanced Ceramics, Inc.):

Braze	Composition	Temp.,°C	Time, min	Load, g
TiCuNi	70Ti,15Cu,15Ni	975	5	30
TiCuSil	68.8 Ag, 26.7Cu, 4.5Ti	910	5	30
Cu-ABA	92.8Cu,3Si,2Al,2.25Ti	1040	5	30

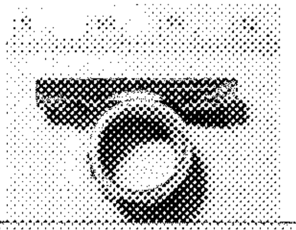
- Specimens were made with outer ply fibers oriented in either parallel to tube direction or perpendicular to tube direction
- Some C/C plates were grooved in order to increase the contact area of the joint

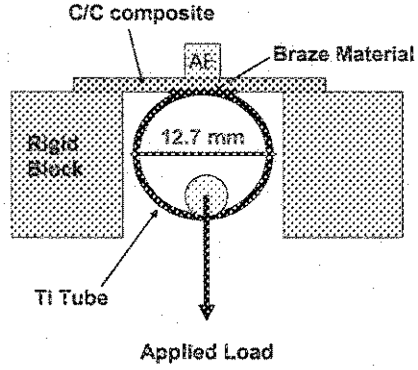
Experimental: Testing and Evaluation

- Tube tensile tests were performed on an Instron 4502
  - Steel leaders (45 lb test, Eagle Claw, Denver, CO)
  - Loading rate of 1mm/min
- The fracture surfaces were analyzed optically to determine the location of joint failure and the area of contact between the tube and the C/C plate
- Modifications were made based on analysis to improve load carrying ability

Tube Tensile Test

To measure the "tensile strength" of the joint



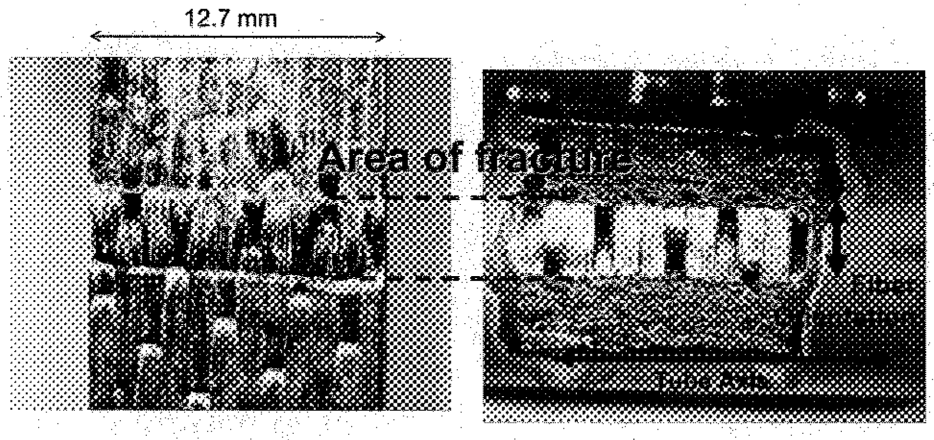


Factors to consider:

- ***Braze composition***
- ***Processing variables***
- ***Bonded area***
- ***Location of failure***
- ***Architecture effects***

TiCuSil Brazed Fracture Surface

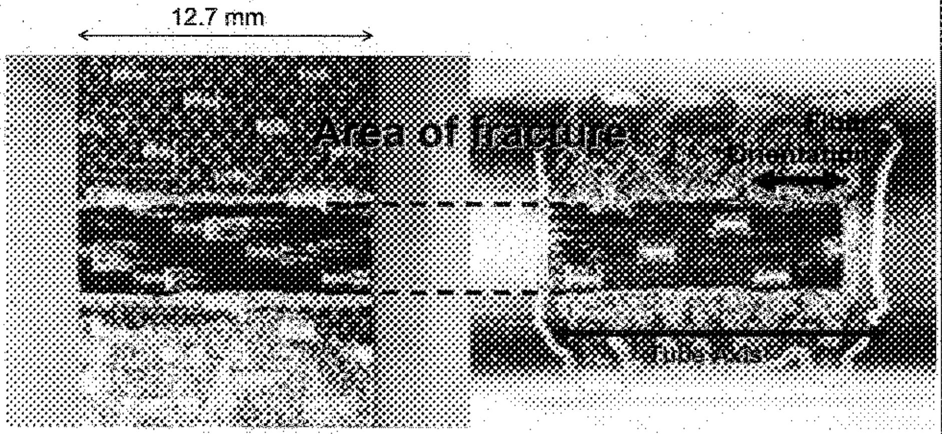
(Perpendicular to the tube axis)



C/C Composite

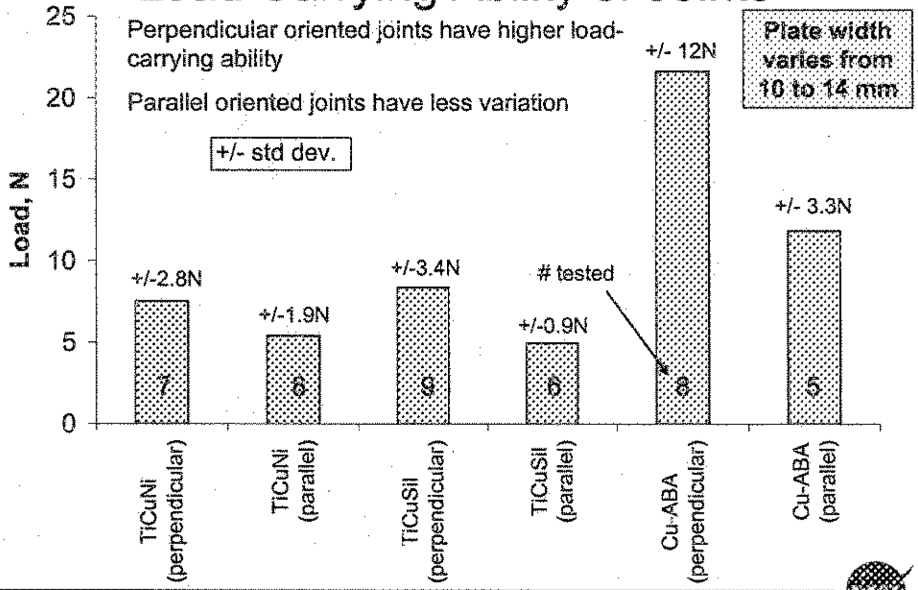
Ti Tube

TiCuSil Brazed Fracture Surface
(Parallel to the tube axis)



EFFECT OF BRAZE COMPOSITION & FIBER ORIENTATION

Load Carrying Ability of Joints



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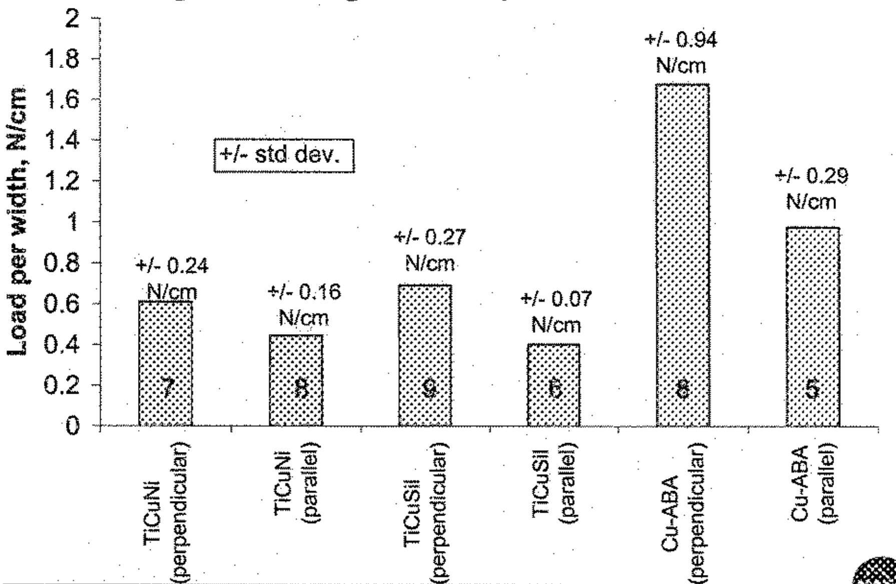
Engineering Load per Plate Width



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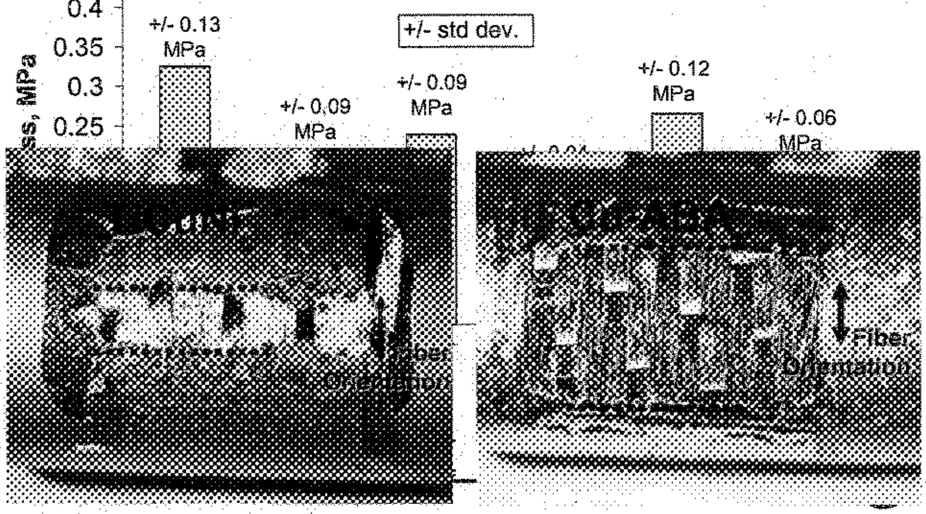
Stress (bonded area) Carrying Ability

Ti-Cu-Ni = Highest "stress" but lowest load-carrying ability

ILSS of C-C plates = 4 MPa – Significantly higher than failure stress

•Failure of joints occurs in outer ply = significant stress-concentration



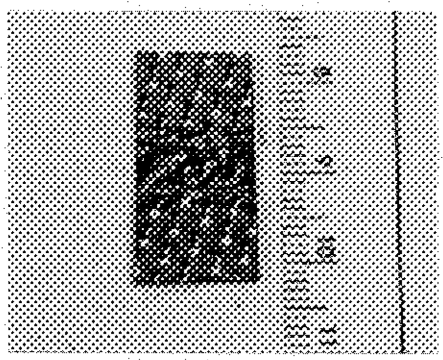
Braze Composition and Fiber Orientation Summary of Results

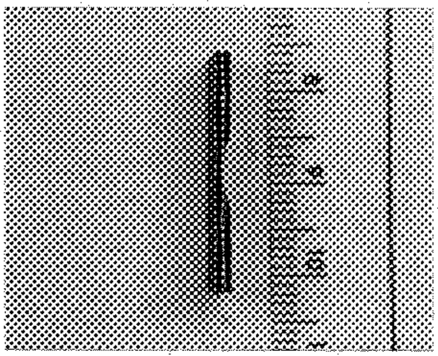
- Cu-ABA has highest load carrying ability
- All fractures occur within the C/C composite
- Composites with surface ply fibers oriented perpendicular to the tube axis were stronger than those with surface ply fibers oriented parallel to the tube axis
- The highest failure loads typically corresponded to the largest fracture areas
  - Ti-Cu-Ni had small contact areas and the highest failure stresses → If contact area could be increased, significant load carrying ability possible

EFFECT OF PROCESSING LOAD
&
C/C PLATE GROOVED SURFACE

(attempts to increase penetration and/or
bonded area)

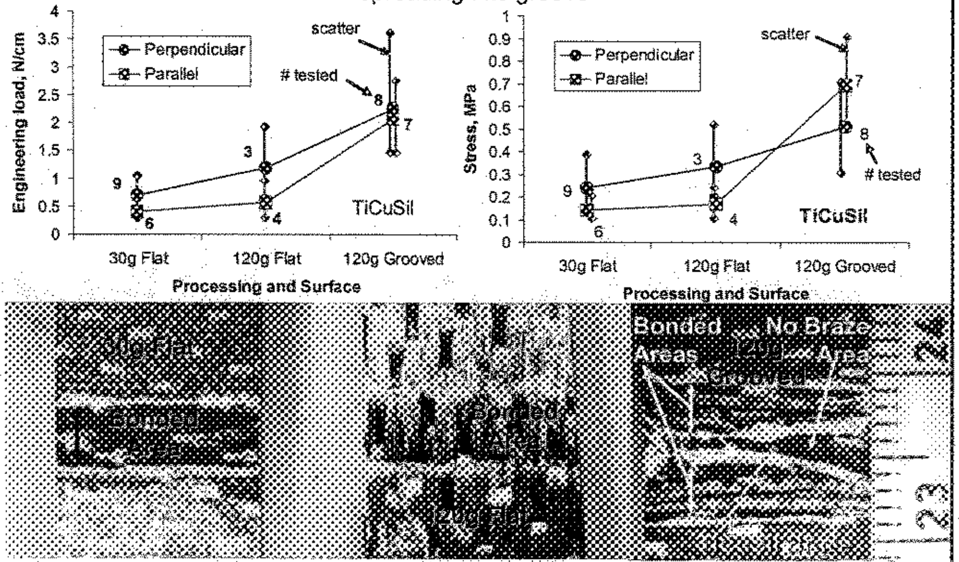
C/C Plate Surface Grooved with "Hand file"





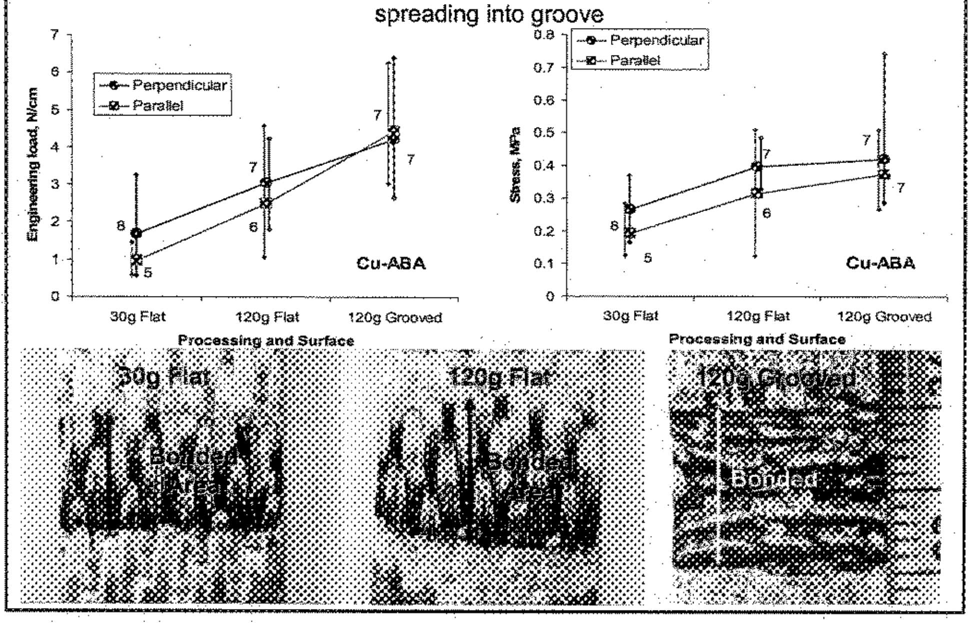
Effect of Processing Load and C/C Surface Condition

Increased bonded area with increasing process load; Poor braze spreading into groove



Effect of Processing Load and C/C Surface Condition

Increased bonded area with increasing process load; Excellent braze spreading into groove



Conclusions

- The tube-plate tensile test proved to be an effective means of evaluating the load carrying ability of the different braze compositions
- Cu-ABA had the best load-carrying ability of the three braze compositions due to superior braze spreading and penetration properties
- Fiber architecture and plate topography also effect load-carrying ability and can be utilized to improve load-carrying ability

Further Study

- Other fiber types, architectures, and configurations
- Adhesives
- Tube-Plate Shear Test